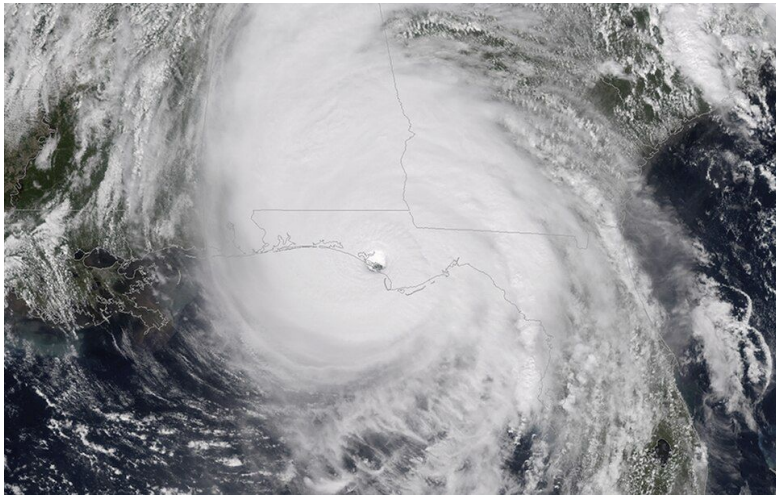
Global Ocean Monitoring and Observing
NATIONAL OCEANIC & ATMOSPHERIC ADMINISTRATION

"Blown Away – Coordinated ocean observations for hurricane forecasting"

Travis Miles, PhD
Assistant Professor
Rutgers University
Center for Ocean Observing Leadership

Contributions from many!

Motivation - A local to global priority

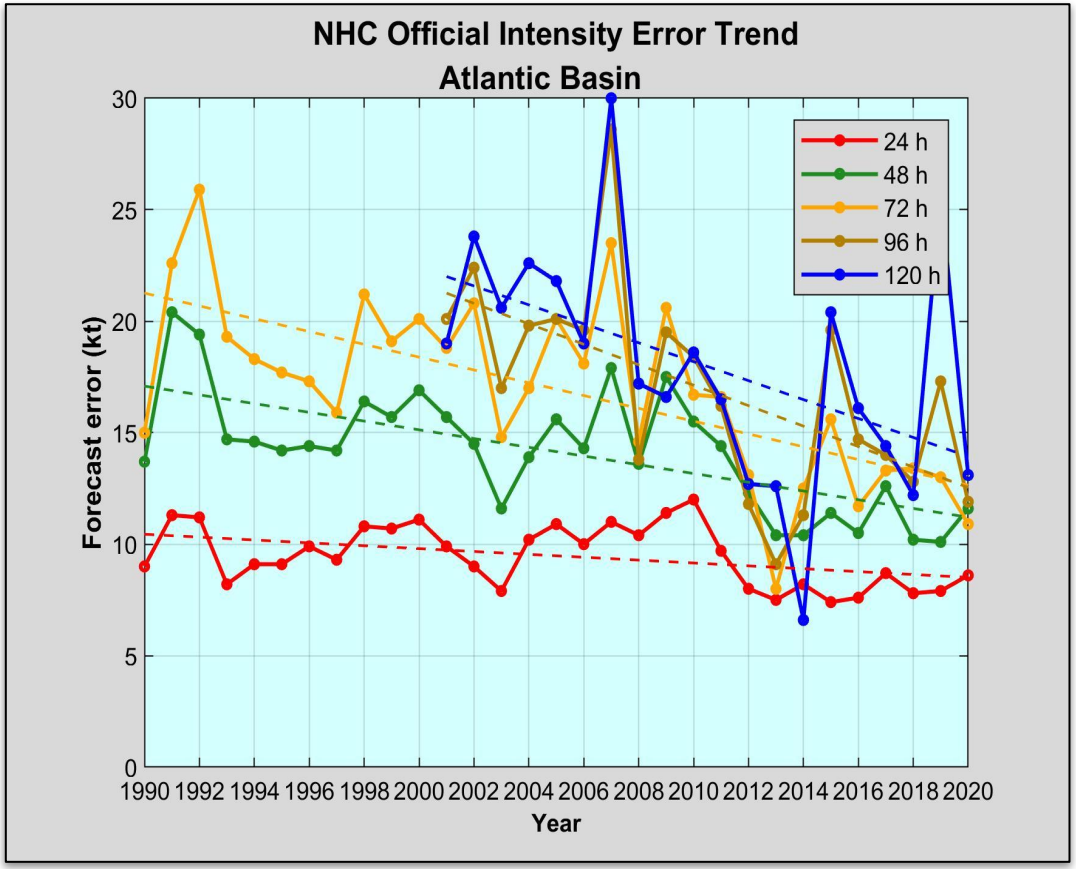


In the U.S. alone tropical cyclones are responsible for over $1.1 trillion in economic losses since 1980 and approaching 7000 deaths. More than all other Billion dollar natural disasters combined.

Globally since 1970 there have been over 500,000 deaths, with a single storm Nargis (2008) responsible for 300,000 in Bangladesh.

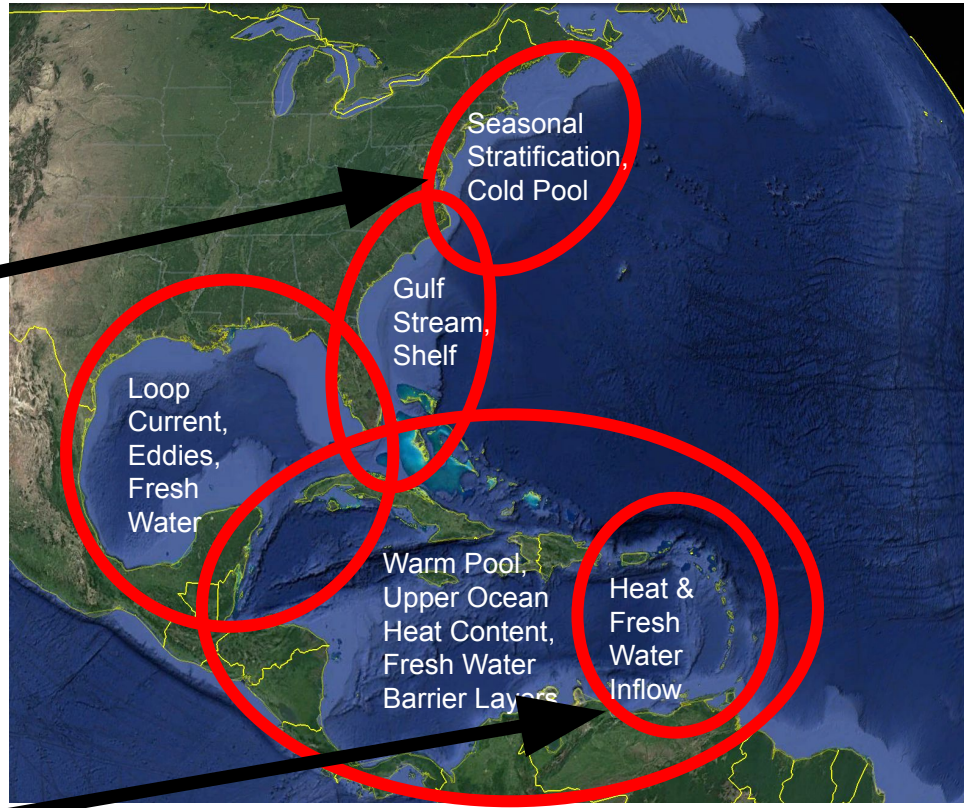
All top 10 tropical cyclone economic losses globally since 1970 have occurred in the U.S. and Puerto Rico. With 4 of the top 5 all occurring after 2005.

Atlantic Hurricane Intensity Forecast Error



- Track error has improved from 300 to 100 nm at 3 days.
- Intensity forecast error has had minimal improvement (~20%)
- Decades of research has solidified the importance of the ocean as a key component of TC intensity change.
- Regional and coastal processes

Disaster Relief Appropriations (2013 Sandy Supplemental) Ocean Observing and Monitoring Division



CINAR
Cooperative Institute for the North Atlantic Region

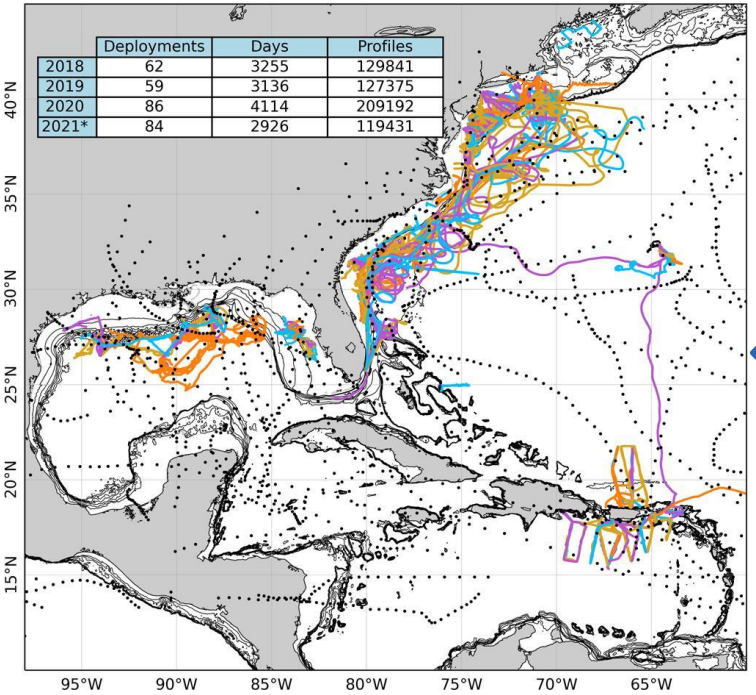
Woods Hole Oceanographic Institution
Rutgers, The State University of New Jersey
University of Maryland – Horn Point
University of Maine
Gulf of Maine Research Institute

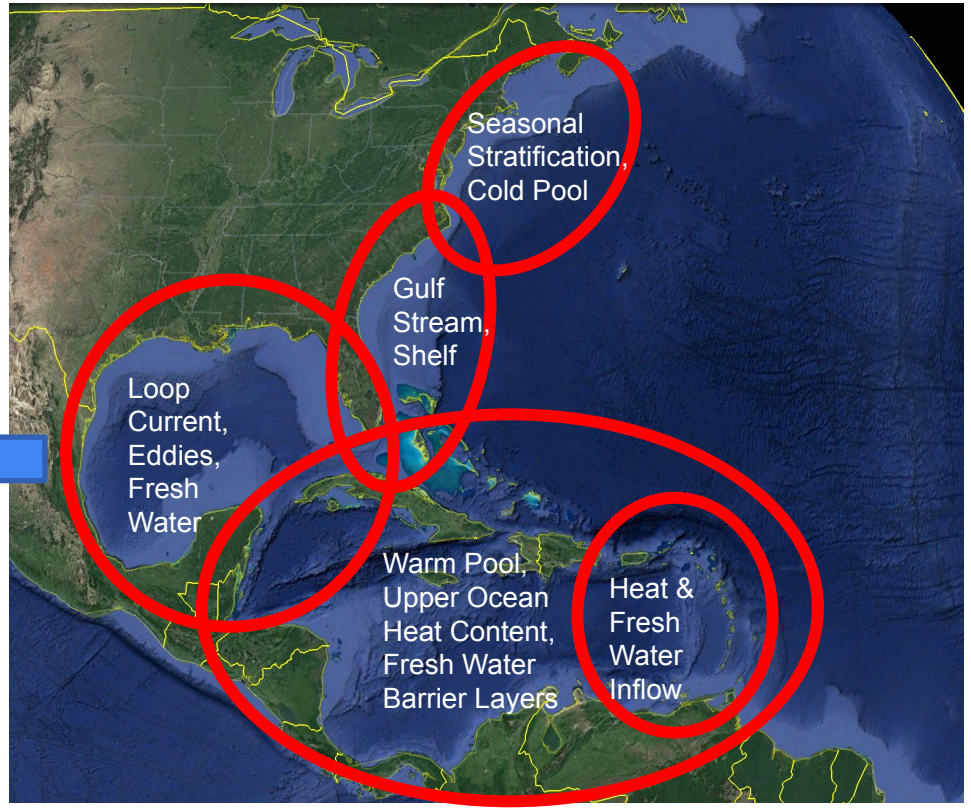
NOAA's Atlantic Oceanographic and Meteorological Laboratory
U.S. Department of Commerce

Domingues et al., 2015; Glenn et al., 2016; Seroka et al., 2016; Seroka et al., 2017; Miles et al., 2017; Dong et al., 2017

NOAA AOML Physical Oceanography Division
University of Puerto Rico Mayaguez

2018 – 2021 Hurricane Glider Program
A Single Platform Network



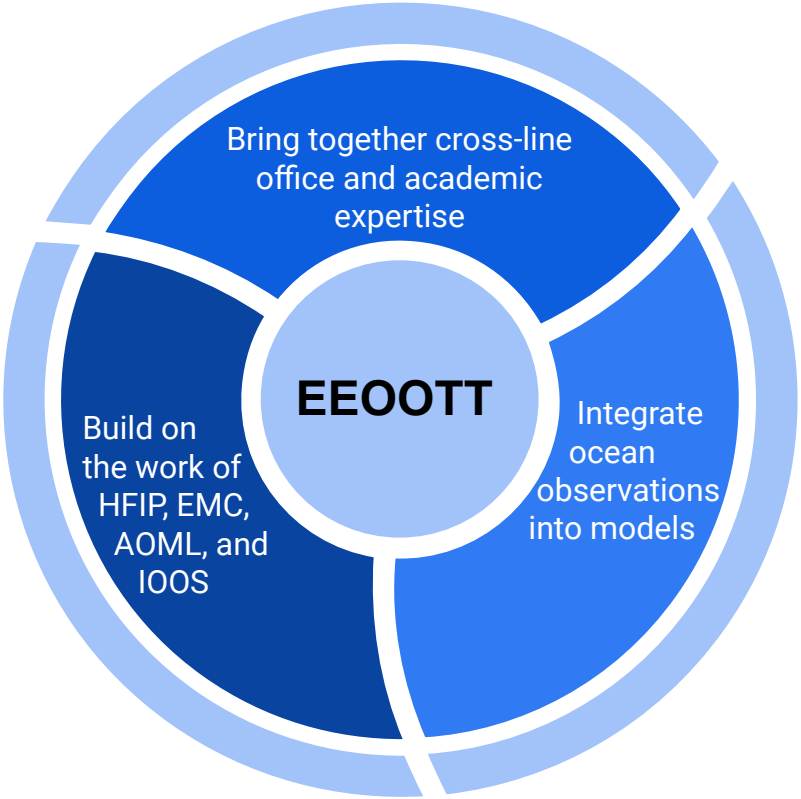


Goal: Real-time <u>targeted & sustained</u> observations to improve ocean representation in coupled forecast models.

Gaps: Primarily operational, need for integration with other ocean/atmosphere observing system, need for pairing observations with research and modeling teams

Extreme Events Ocean Observations Task Team (EEOOTT)

- **Spring 2020**: Inception, stakeholder/observing system operator engagement – Small group meetings (My engagement started)



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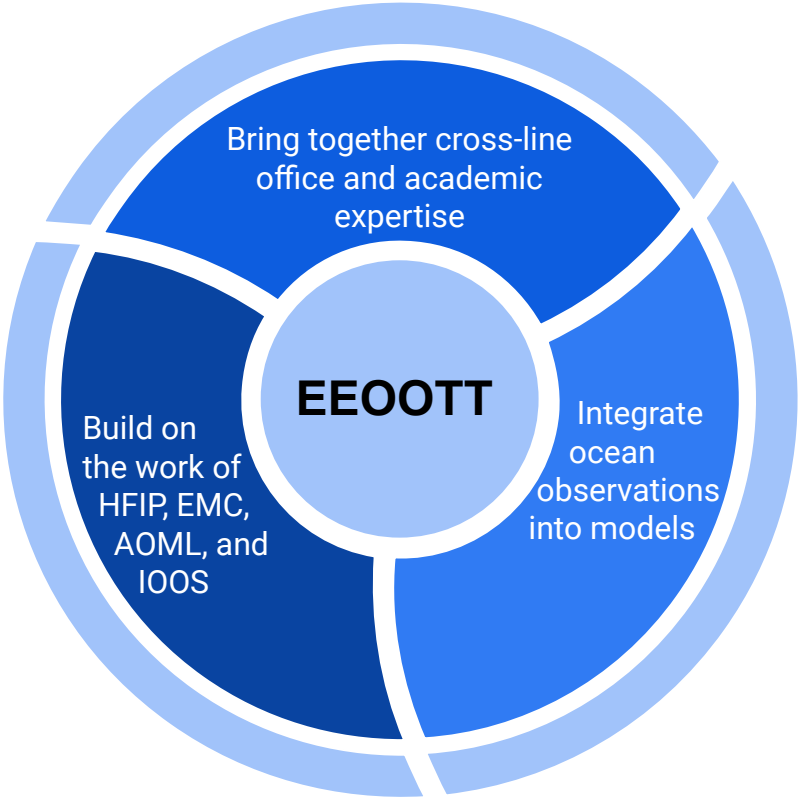

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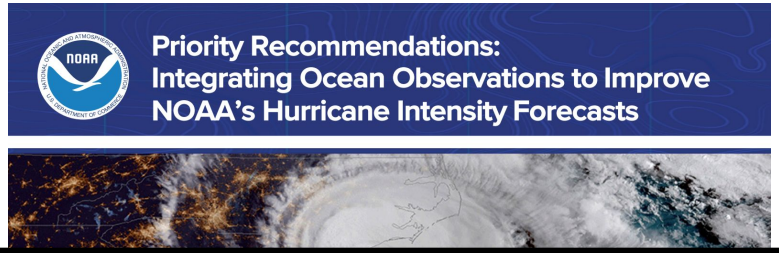

- **Coordinate efforts** to **close gaps** in ocean and transition zone observations
- **Evaluate** the **impacts** of ocean and transition zone observations on hurricane **intensity forecasts**
- **Improve assimilation** of ocean and transition zone observations into **numerical modeling systems**
- **Prioritize** and recommend ocean and transition zone observations for **future operational investment**

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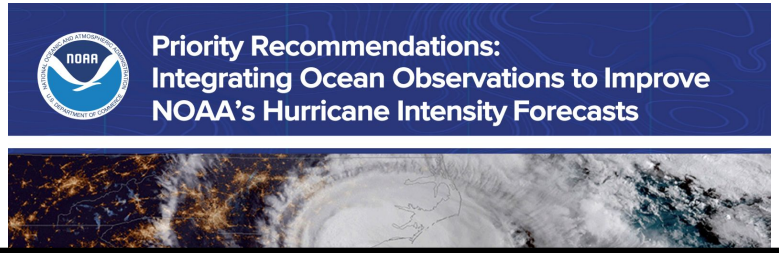

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Ocean Obs Task Team: Carries out weekly coordination meetings during hurricane (2021 and 2022). Shared through the HRD HFP weekly. Modified and adjusted deployments based on multi-platform data coverage.

IMPACT Team: The Integrated Modeling Prediction Assimilation Coordination Team is an interagency group that focuses on assessing the impact of ocean observations in NOAA's coupled forecast systems and hurricane intensity forecasts to improve data assimilation and hurricane modeling systems.

Both include coordinated teams of ocean observation operators, ocean modeling and data assimilation experts: NOS, AOML, PMEL, OPC, NWS, HRD, WHOI, Rutgers, MSU, Miami, UVI, UPR, (many other academia), private companies, and the Naval Research Laboratory.

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- **Hurricane Season 2021**: Participated in AOML/HRD Hurricane Field Program; coordinated observations for 5 TCs including Ida

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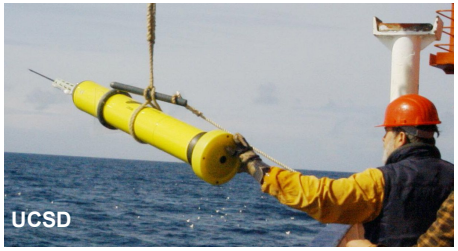
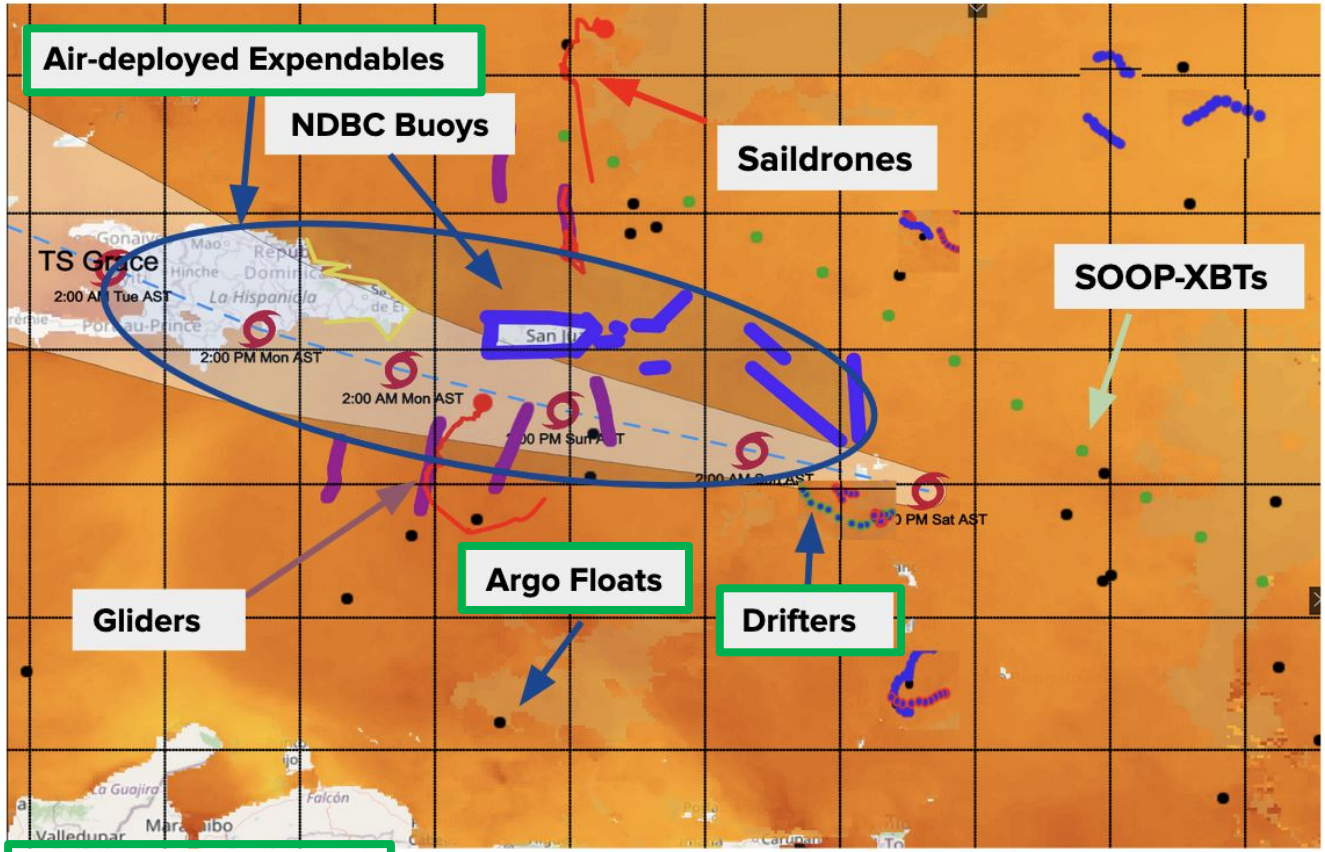
Multi-platform ocean observing network

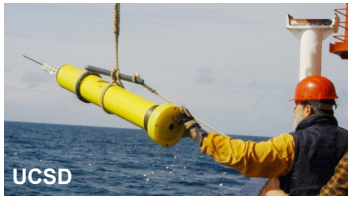




GOMO Funded

Hurricane Grace (2021) in the Caribbean region

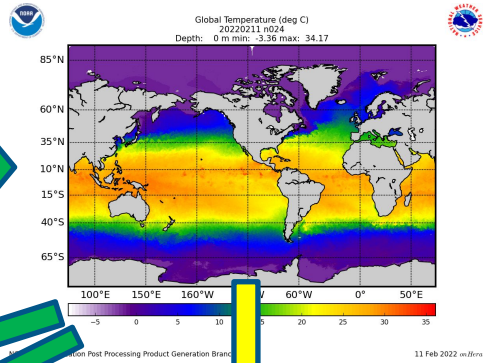
Operational Systems: Hurricane Forecasting Suite



Platform Data Repository

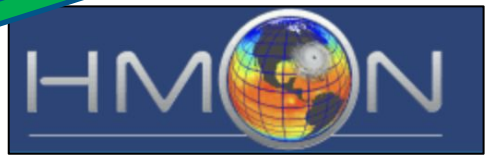
WMO GTS

NOAA RTOFS 2.0

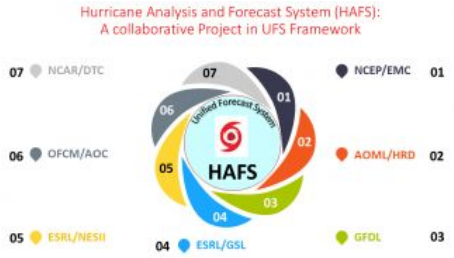


Regional Coupled Ocean-Atmosphere Hurricane Forecast Models

Operational
HWRF + MPIPOM using
RTOFS Initial Condition



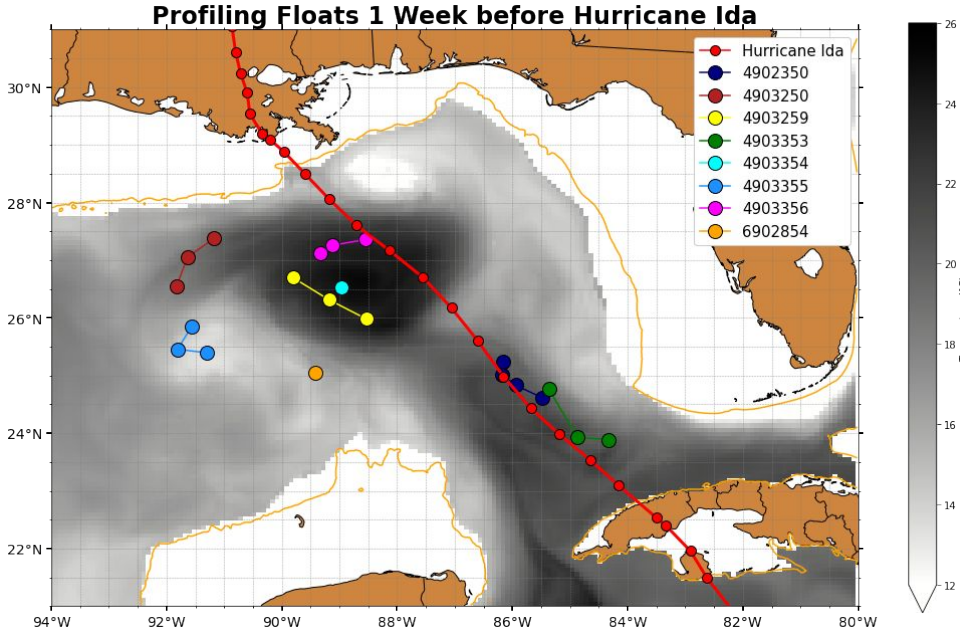
Operational
HMON + HYCOM using
RTOFS Initial Condition



Experimental
HAFS + HYCOM
RTOFS Initial Condition

Example - Rapid Argo Cycling for Hurricane Forecasts

- 50 Argo floats in the Gulf of Mexico and Caribbean were *rapid cycling* (2.5 vs. 10 day cycling)
- Rutgers is currently working to assess the impact of these rapidly cycled floats on RTOFS - which is used to initialize the coupled operational hurricane forecast models
- Beneficial for **better understanding T, S, OHC, potential energy anomalies**, etc. throughout the season and in advance of an approaching storm
- GOMO EEOOTT facilitated connection of operator team (WHOI) to data model impact evaluation team (Rutgers).



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RUTGERS

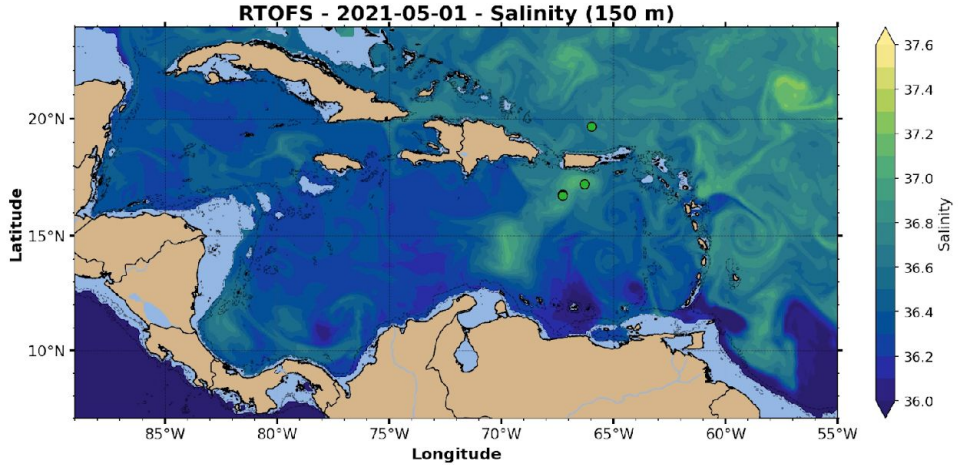
Argo

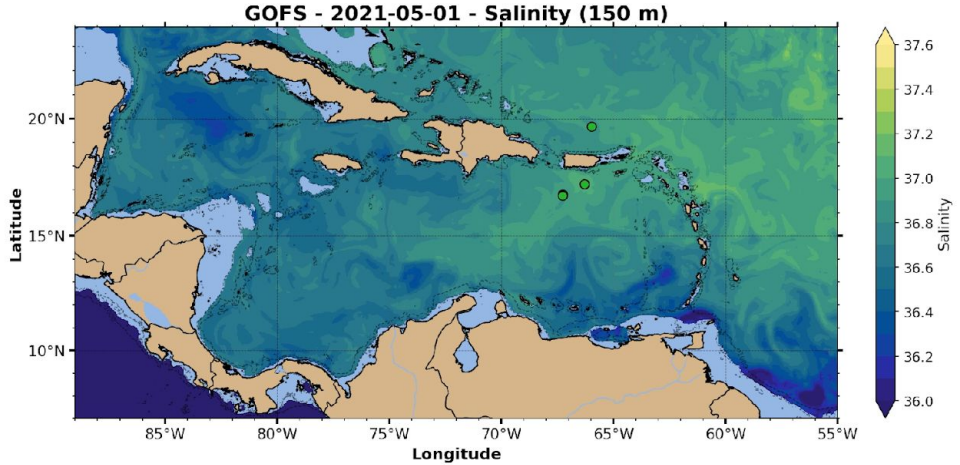
WOODS HOLE OCEANOGRAPHIC INSTITUTION
1930

Current and Future Directions

- Integrated Field Campaign Planning
- Hurricane Season 2022
- Ocean Decade Co-design – bringing in international partners

Additional Slides


RTOFS - 2021-05-01 - Salinity (150 m)
Latitude
Longitude
20°N
15°N
10°N
85°W
80°W
75°W
70°W
65°W
60°W
55°W
Salinity
37.6
37.4
37.2
37.0
36.8
36.6
36.4
36.2
36.0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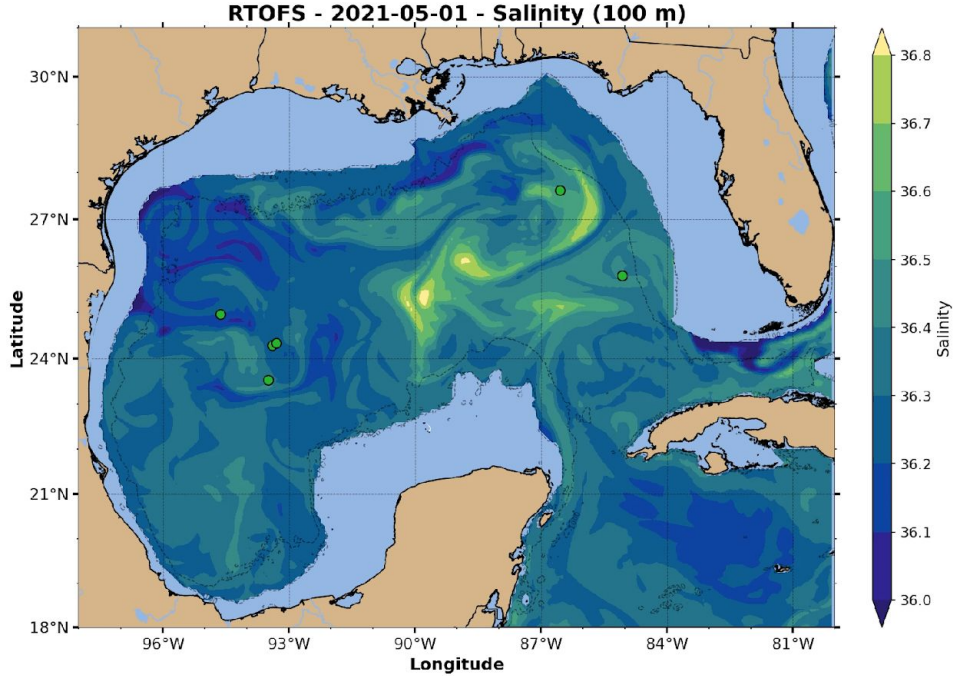
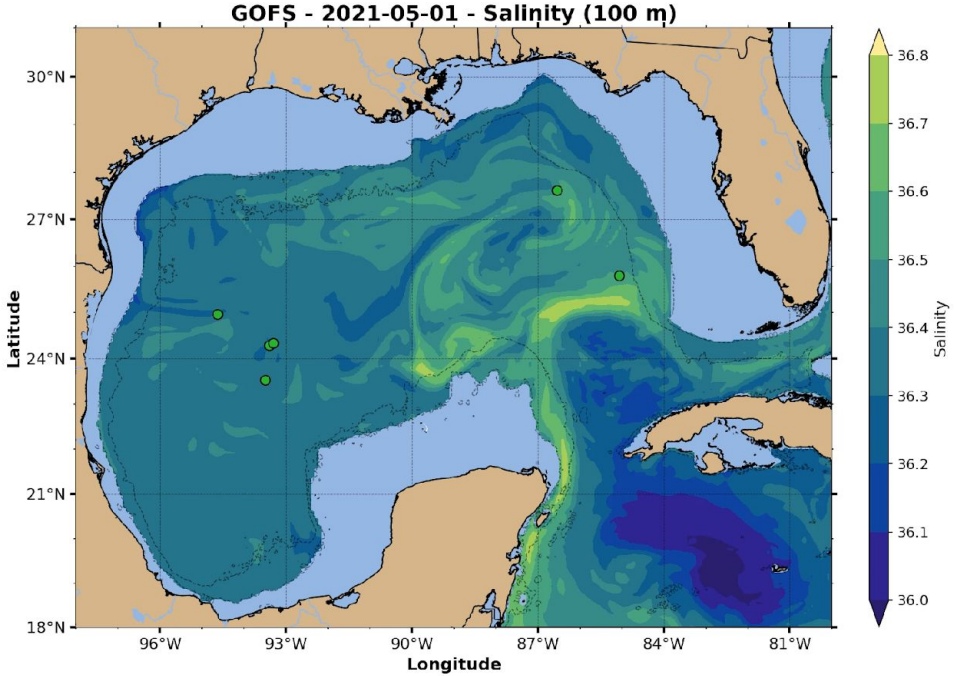

RTOFS - 2021-05-01 - Salinity (100 m)
30°N
27°N
24°N
21°N
18°N
Latitude
96°W
93°W
90°W
87°W
84°W
81°W
Longitude
36.8
36.7
36.6
36.5
36.4
36.3
36.2
36.1
36.0
Salinity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36.0
Salinity

Table 1. Top 10 disasters ranked according to reported (a) deaths and (b) economic losses (1970–2019)[8]

(a)	Disaster type	Year	Country	Deaths
1	Drought	1983	Ethiopia	300 000
2	Storm (*Bhola*)	1970	Bangladesh	300 000
3	Drought	1983	Sudan	150 000
4	Storm (*Gorky*)	1991	Bangladesh	138 866
5	Storm (*Nargis*)	2008	Myanmar	138 366
6	Drought	1973	Ethiopia	100 000
7	Drought	1981	Mozambique	100 000
8	Extreme temperature	2010	Russian Federation	55 736
9	Flood	1999	Bolivarian Republic of Venezuela	30 000
10	Flood	1974	Bangladesh	28 700

Table 1. Top 10 disasters ranked according to reported (a) deaths and (b) economic losses (1970–2019)[8]

(b)	Disaster type	Year	Country	Economic losses (in US$ billion)
1	Storm (*Katrina*)	2005	United States	163.61
2	Storm (*Harvey*)	2017	United States	96.94
3	Storm (*Maria*)	2017	United States	69.39
4	Storm (*Irma*)	2017	United States	58.16
5	Storm (*Sandy*)	2012	United States	54.47
6	Storm (*Andrew*)	1992	United States	48.27
7	Flood	1998	China	47.02
8	Flood	2011	Thailand	45.46
9	Storm (*Ike*)	2008	United States	35.63
10	Flood	1995	Democratic People's Republic of Korea	25.17

U.S. Billion-Dollar Weather & Climate Disasters: 1980-2021

NOAA NATIONAL CENTERS FOR ENVIRONMENTAL INFORMATION
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Disaster Type	Events	Percent of Total Events	Costs	Percent of Total Costs	Deaths	Percent of Total Deaths
Tropical Cyclone	**56**	**18.1%**	**$1,148.0B**	**53.2%**	**6,697**	**44.1%**
Severe Storm	143	46.1%	$330.7B	15.3%	1,880	12.4%
Drought	29	9.4%	$285.4B	13.2%	4,139	27.2%
Flooding	35	11.3%	$164.2B	7.6%	624	4.1%
Wildfire	19	6.1%	$120.2B	5.6%	401	2.6%
Winter Storm	19	6.1%	$78.6B	3.6%	1,277	8.4%
Freeze	9	2.9%	$32.8B	1.5%	162	1.1%
All Disasters	**310**	**100.0%**	**$2,159.9B**	**100.0%**	**15,180**	**100.0%**

https://www.ncdc.noaa.gov/billions/

Top 10 tropical cyclones by number of deaths globally (1970 -2019)

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4	Storm	1985	Bangladesh	15 000
5	Storm (*Mitch*)	1998	Honduras	14 600
6	Storm	1977	India	14 204
7	Storm (05B)	1999	India	9 843
8	Storm	1971	India	9 658
9	Storm (*Fifi*)	1974	Honduras	8 000
10	Storm (*Haiyan*)	2013	Philippines	7 354

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Top 10 tropical cyclones by economic losses globally (1970 -2019)

(b)	Disaster type	Year	Country/territory	Losses in US$ billion
1	Storm (*Katrina*)	2005	United States	163.61
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9	Storm (*Charley*)	2004	United States	21.65
10	Storm (*Rita*)	2005	United States	20.94

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